MANAGEMENT OF AREAS POLLUTED BY RADIOACTIVES SUBSTANCES: THE UPDATED FRENCH APPROACH

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Abstract: Over the last 20 years, the French public services' actions in the field of polluted areas have continuously evolved from the inventory of potentially polluted areas to the statement of a general framework on the management. Initially designed for chemical pollutants, main guidelines have been implemented for radioactive substances. The general framework is presented hereafter and illustrated with a real example.

1. CONTEXT

In the 90's, French administration developed a series of tools to set up an inventory of potentially polluted sites and to identify places requiring an immediate action. By early 2000s, such tools, initially designed for chemical pollution, were adapted to radioactive pollutants.

Based on feedback gained over a decade, the revision of available tools was undertaken by the French Ministry of Ecology in 2006 to state a general framework on the management of polluted areas. Guidelines were published in a ministerial order in 2007, attesting public services' concerns and needs evolution from the establishment of the inventory of polluted sites and the selection of those requiring immediate actions to the definition of a methodology for their management.

Considering radioactive pollution, France deals with sites inherited from nuclear research and development activities and the industry of radium or other radionuclides like tritium. For instance many working places associated with the storied history of Pierre and Marie Curie are still polluted by ^{226}Ra and progenies. Sites where former NORM and TENORM facilities were operated may also be considered as polluted area especially when residues were left over. The management of these areas has to be consistent with the general framework published by the ministry of Ecology in 2007.

The French Institute for Radiological protection and Nuclear Safety (IRSN) was committed by the French Ministry of Ecology and the French Nuclear Safety Authority (ASN) to establish guidelines on the management of areas polluted by radioactive substances. Requirements were: i) to fit with the published rules highlighting specifics of radioactive pollutants; ii) to take benefit from former radioactive polluted areas management; iii) to precisely define remediation objectives and iv) to develop stakeholders involvement issues.

A first draft of guidelines was elaborated by a working group composed of representatives from IRSN, the Ministry of Ecology, ASN and the French National Institute for industrial Environment and Risks (INERIS). Statement of remediation objectives was conducted in a pluralist group, chaired by members of the ministry of Ecology and the ASN and composed of representatives from public services', French and foreign experts as well as NGOs' and elected people representatives. This first draft guidlines was submitted to public consultation for three months on internet.

2. FRAMEWORK ON THE MANAGMENT OF POLLUTED AREAS

Remediation actions should be defined to be consistent with the actual or future use of the polluted site. Therefore, two situations can be distinguished: i) sites with established uses and ii) urban and industrial wasteland or sites at a dismantling and redevelopment stage. In the first case, called 'interpreting the condition of environment", compatibility between established uses and pollution level has to be assessed. In the second case, called "Management plan", the decision-making process and should consider the pros and cons for the different remediation options considering: residual effective dose, short and long term efficiency, as well as waste management and associated cost. It is not only applicable to wasteland management, dismantling and redevelopment projects but also to polluted sites with ongoing uses when compatibility between pollutions and uses is not established.

Whatever the situation, the management requires a site characterization including not only radiological measurements but also the description of established or planed uses, as well as identification of resources to be protected (water, animals, plants…). Site characterisation is based on documentary survey and field investigations. Collected data should be reported in a conceptual scheme describing the different issues including pollution sources pathways and identified exposure situations. The general framework of the overall polluted area management is illustrated in figure 1.

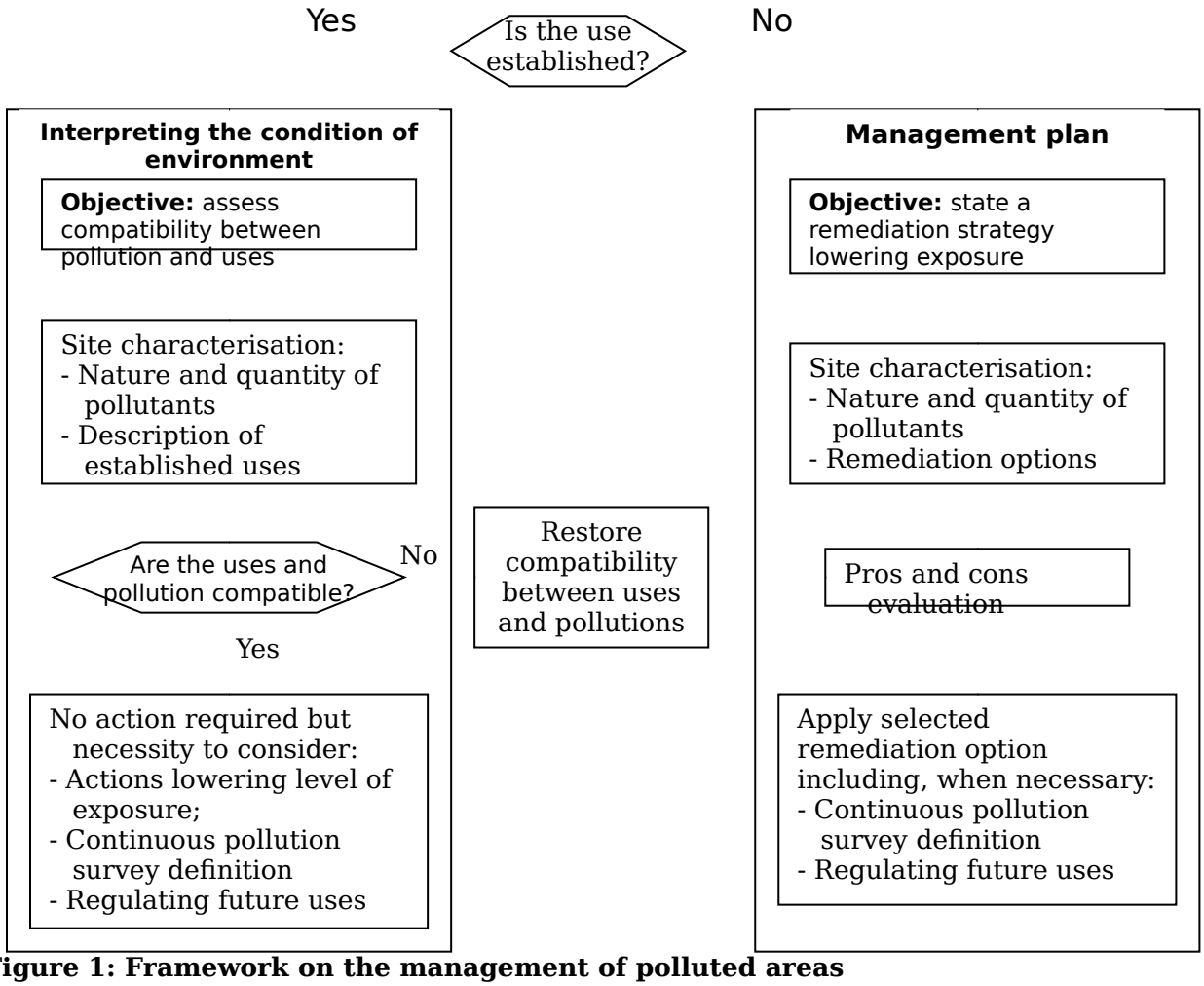

Figure 1: Framework on the management of polluted areas

2.1 Interpreting the condition of environment

The decision making process for the management of pollutions on a site with established uses starts with the assessment of pollution levels. It is based on a comparison of pollutant concentrations with a reference level. This reference level can be either established before industrial activities has started or, when not available, the determined during the site characterisation. The first aim of this exercise is to confirm or not the presence of a pollution. When the pollution is confirmed, the level of contamination is compared to threshold values defined in existing regulations to assess the compatibility of pollution with respect to established land uses.

Threshold values to be considered are:

- **the radiological content in drinking water**. The national regulation imposes to check gross alpha, gross beta and tritium activity concentrations. Corresponding threshold values are respectively 0.1 $Bq.L^{-1}$, 1 $Bq.L^{-1}$ and 100 $Bq.L^{-1}$. When activity concentrations are higher than defined values, an effective dose resulting from the consumption of two litres of water per day throughout the year is assessed. Radionuclide to be considered in that case are ^{238}U, ^{234}U, ^{226}Ra, ^{210}Pb, ^{210}Po and ^{228}Ra for natural radionuclide and ^{90}Sr, ^{238}Pu, $^{239+240}Pu$, ^{241}Am and ^{137}Cs for artificial ones. If the effective dose is lower than 0.1 $mSv.an^{-1}$ no restriction is applied. If the effective dose is in the range of 0.1-0.3 $mSv.yr^{-1}$, implementation of remediation actions is recommended. Between 0.3 and 1 $mSv.yr^{-1}$, options to lower exposure levels have to be foreseen. Finally, if the effective dose is higher than 1 $mSv.yr^{-1}$, remediation action has to be executed. In addition to that, the value of 15µg.L^{-1} of uranium, stated by the world health organisation may be considered.

- **radon concentration activity in buildings**. Regulation applicable to public places (schools, hospital, jail, administrative buildings,…) proposes the limit of 400 $Bq.m^{-3}$ to engage remediation action. This value is also retained for the regulation of exposure to radon in working places, especially underground ones. Following international decisions, France is carrying out its regulation to fix limits in private building and the value of 300 $Bq.m^{-3}$, recommended by international organisations (International commission for Radiological Protection and World Health Organisation) may constitute a reference level.

- **contamination of foods**. Regulation of radioactivity in food has been carried out to define admissible levels of contamination in case of nuclear accident or to regulate trade of foods contaminated by radioactive fallouts. The corresponding values concern only artificial radionuclide and are not strictly applicable to inheritate sites polluted by radioactive substances. Nevertheless, they can constitute a reference level.

- local regulation established to monitor and limit the impact of local industries may also be considered.

When no threshold value for the radionuclide affecting a compartment of the environment is established, a dose assessment is required. A tool describing the way to conduct a dose assessment is proposed in the document. It consists in a general and mathematical description of the following 11 scenarios:

- incursion on wasteland
- building construction site
- indoor working places
- dwelling places
- parking areas use
- market gardening activities
- professional activity
- home place

- school
- stadium
- leisure centre

To judge the compatibility of the use with respect to the pollution levels, the result of dose assessment has to be compared to the reference value of 1 $mSv.yr^{-1}$ in addition to the local exposure background. This value constitutes a reference for conducting actions. However, options allowing to reduce exposure have to be considered even below this value in application of the “as low as reasonably achievable” principle. Depending on the context, lower objectives may be imposed by administration, specifically when pollution affects areas involving sensitive population (children, patients…).

2.2 Management plan

The decision making process corresponding to the management plan is implemented on sites with no established land uses (wasteland, dismantling and redevelopment project) or when the “interpretation of the condition of environement” concludes that pollution and established uses are not in agreement (figure 1).

The final goal is to assure, or restore, the compatibility between pollution levels and land uses. The ways to proceed is to master sources of pollution and, when necessary, to limit pollution and exposure pathways.

Different remediation options have to be designed and their pros and cons considered. Criteria to take into account are residual effective dose, short and long term efficiency, as well as waste management and associated cost.

Removing all the radioactive pollution corresponds to the reference option. However this option may not be technically or financially not realistic, therefore options limiting exposure are then required. Separately or combined, partial clean-up, containment of pollution, adaptation of the redevelopment project to the residual pollution to limit exposure pathways should be considered. For example road or parking establishment would be preferable to buildings or kid garden establishment on areas not completely free of pollution.

After remediation, residual pollution has to respect threshold values presented in the previous section. In the case of a “management plan”, the objective is to lower exposures. Therefore those values constitute upper limits and the remediation objectives have to be set as low as possible below those reference values.

3. EXAMPLE

The example corresponds to a former industrial site of radium extraction from uranium ore at the beginning of the 20^{th} century. Investigations were conducted in 1997 and 1998 on the site and its close environment. They concluded to a radioactive pollution, mainly located in the industrial site.
In 2008, IRSN was committed by the French ministry of Ecology to interpret the condition of environment of areas around this industrial site.

Radiological investigations carried out by IRSN aimed to assess the sanitary impact on the former industrial site and its vicinity.

As recommended by guidelines, IRSN carried out an historical analysis. Main source of information was aerial pictures of the area taken between 1933 and now. In addition, environmental, urban, geological, hydrological and hydrogeological contexts were

studied to identify potential pathways of pollutants and corresponding issues. Conclusions of historical and vulnerability studies allowed to draw a conceptual scheme including potential source of pollution location, transfer pathways, potential targets and exposure pathways.

To interpret the condition of environment, additional field investigations were required. IRSN carried out radiological measurements in soil, air and water on a surface of about ten hectares around the former industrial site. The methodology adopted was to establish a dose rate map according to a defined mesh. The objective was to select places for soil and underground water sampling from drillings (up to 4 m). Soil and water samples were analysed on field using gamma detectors operated in the laboratory vehicle of IRSN. (7 piezometers and 70 soil cores). Gamma emitters from the natural radioactive chain of uranium 238, uranium 235 and thorium 232 were investigated. A special attention was given to short live ^{226}Ra daughters. To complete the pollution caracterisation, activity concentration of radon gas in buildings was measured. Similar investigations were carried out in the environment out of the influence of the old industrial site to quantify the natural background and assess the level of pollution.

Theses investigations highlighted few small areas of soil polluted by ^{226}Ra and daughters as well as a transfer of uranium (up to 200 µg.L^{-1}) to underground water.

Considering national regulation, exposure levels (excluding radon) due to pollution was considered to be negligible in the whole investigated area excluding a building adjacent to the former industrial site. In this building, radon activity concentration was over the limit of 400 Bq.m^{-3}. Waiting for the implementation of remediation actions to lower exposure of workers, access was restricted.

Considering remediation and rehabilitation options, IRSN has recommended to clean up the site by removing contaminated soil. If this option would be technically not possible or jugged too expensive, IRSN suggests to follow the quality of the waters and to keep the memory of pollution by regulating the future uses. On field remediation operations have to be radiologically supervised.

Guidelines are available (in French) on:

- www.sites-pollues.developpement-durable.gouv.fr
- www.asn.fr
- www.irsn.fr/consultation-guide-ssp